

Electrical injury

An **electrical injury** (**electric injury**) or **electrical shock** (**electric shock**) is damage sustained to the [skin](#) or internal organs on direct contact with an [electric current](#).^{[2][3]}

The injury depends on the [density of the current](#), tissue resistance and duration of contact.^[4] Very small currents may be imperceptible or only produce a light tingling sensation. However, a shock caused by low and otherwise harmless current could startle an individual and cause injury due to jerking away or falling. A strong electric shock can often cause painful [muscle spasms](#) severe enough to [dislocate joints](#) or even to [break bones](#). The loss of muscle control is the reason that a person may be unable to release themselves from the electrical source; if this happens at a height as on a [power line](#) they can be thrown off.^{[5][6]} Larger currents can result in tissue damage and may trigger [ventricular fibrillation](#) or [cardiac arrest](#).^[7] If death results from an electric shock the [cause of death](#) is generally referred to as [electrocution](#).

Electric injury occurs upon contact of a body part with [electricity](#) that causes a sufficient current to pass through the person's tissues. Contact with energized [wiring](#) or devices is the most common cause. In cases of exposure to high [voltages](#), such as on a [power transmission tower](#), direct contact may not be necessary as the voltage may "[jump](#)" the [air gap](#) to the electrical device.^[8]

Following an electrical injury from household current, if a person has no symptoms, no underlying heart problems, and is not pregnant further testing is not required.^[9] Otherwise an [electrocardiogram](#), blood work to check the heart, and urine testing for signs of muscle breakdown may be performed.^[9]

| Electrical injury | |
|--|---|
| Other names | Electrical shock |
|  | |
| Lightning injury caused by a nearby lightning strike . The slight branching redness (sometimes called a Lichtenberg figure) travelling up the leg was caused by the effects of current. | |
| Specialty | Emergency medicine |
| Complications | Burns , rhabdomyolysis , cardiac arrest , bone fractures ^[1] |
| Frequency | >30,000 per year (USA) ^[1] |
| Deaths | ~1,000 per year (USA) ^[1] |

Management may involve [resuscitation](#), pain medications, wound management, and [heart rhythm monitoring](#).^[9] Electrical injuries affect more than 30,000 people a year in the [United States](#) and result in about 1,000 deaths.^[1]

Signs and symptoms

Burns



Second-degree burn after a [high tension line](#) accident

Heating due to [resistance](#) can cause extensive and deep [burns](#). When applied to the hand, electricity can cause involuntary muscle contraction, preventing the victim from untensing their hand muscles and releasing the wire, increasing the risk for serious burns.^[10] Voltage levels of 500 to 1000 volts tend to cause internal burns due to the large energy (which is proportional to the duration multiplied by the square of the voltage divided by resistance or the square of the current multiplied by the resistance) available from the source. Damage due to current is through tissue heating and/or electroporation injury. For most cases of high-energy electrical trauma, the Joule heating in the deeper tissues along the extremity will reach damaging temperatures in a few seconds.^[11]

Ventricular fibrillation

A domestic power supply voltage (110 or 230 V), 50 or 60 Hz [alternating current](#) (AC) through the chest for a duration longer than one second may induce [ventricular fibrillation](#) at currents as low as 30 milliamperes (mA).^{[12][13]} With [direct current](#) (DC), 90 to 130 mA are required at the same duration.^[14] If the current has a direct pathway to the heart (e.g., via a [cardiac catheter](#) or other kind of [electrode](#)), a much lower current of less than 1 mA (AC or DC) can cause fibrillation. If not immediately treated by [defibrillation](#), ventricular fibrillation is usually lethal, causing [cardiac](#)

arrest, because all of the [heart muscle fibres](#) move independently instead of in the [coordinated action](#) needed for successful [cardiac cycle](#) to pump blood and maintain circulation. Short single DC pulses induce [VF](#) dependent on the amount of charge (in [mC](#)) transferred to the body, which makes the amplitude of the electrical stimulus independent of the exact amount of current flowing through the body for very short pulse durations. DC shocks of short duration are usually better tolerated by the heart even at high currents and rarely induce ventricular fibrillation compared to lower currents with longer duration with both DC or AC. The amount of current can easily reach very high values as [amperage](#) is only of second order importance to fibrillation risk in the case of ultra short contact times with direct currents. But even if the charge itself is harmless, the amount of energy being discharged still can lead to thermal and chemical hazards if its value is high enough. One example of high current electric shock which may be usually harmless is an [electrostatic discharge](#) as experienced in everyday life on door handles, car doors etc. These currents can reach values up to 60 A without harmful effects on the heart as the duration is in the order of only several [ns](#). Another example for dangerous electrostatic discharges even without flowing directly through the body are lightning strikes and high voltage arcs.

Mechanism

Mechanism of cardiac arrhythmias induced by electricity is not fully understood, but various biopsies have shown [arrhythmogenic foci](#) in patchy [myocardial fibrosis](#) which contained increased amount of [Na⁺](#) and [K⁺ pumps](#), possibly associated with transient and localized changes in [sodium-potassium transport](#) as well as their concentrations, resulting in changes in [membrane potential](#).^{[13][15]}

Neurological effects

Electric current can cause interference with nervous control, especially over the heart and lungs. Electric shock which does not lead to death has been shown to cause [neuropathy](#) in some cases at the site where the current entered the body.^[10] The neurologic symptoms of electrical injury may occur immediately, which traditionally have a higher likelihood for healing, though they may also be delayed by days to years.^[10] The delayed neurologic consequences of electrical injury have a worse [prognosis](#).^[10]

When the path of electric current proceeds through the head, it appears that, with sufficient current applied, loss of consciousness almost always occurs swiftly. This is borne out by some limited [self-experimentation](#) by early designers of the [electric chair](#) and by research from the field of [animal husbandry](#), where [electric stunning](#) has been extensively studied.^[16]

If ventricular fibrillation occurs (as above), the blood supply to the brain is diminished, which may cause [cerebral hypoxia](#) (and its associated neurologic consequences).

Mental health

There are a variety of psychiatric effects that may occur as a result of electrical injuries.

Behavioral changes can occur as well, even if the path of electric current did not proceed through the head.^[10] Symptoms may include:^[10]

- [Depression](#), including feelings of low self-esteem and guilt
- [Anxiety](#) spectrum disorders, including [posttraumatic stress disorder](#) and fear of electricity
- Moodiness, including a lower threshold for frustration and "losing one's temper"
- Memory loss, decreased attention span, and difficulty learning

Arc-flash hazards

[OSHA](#) found that up to 80 percent of its electrical injuries involve thermal burns due to arcing faults.^[17] The [arc flash](#) in an electrical fault produces the same type of light [radiation](#) from which electric welders protect themselves using face shields with dark glass, heavy leather gloves, and full-coverage clothing.^[18] The heat produced may cause severe burns, especially on unprotected flesh. The arc blast produced by vaporizing metallic components can break bones and damage internal organs. The degree of hazard present at a particular location can be determined by a detailed analysis of the electrical system, and appropriate protection worn if the electrical work must be performed with the electricity on.

Pathophysiology

The minimum current a human can feel depends on the current type ([AC](#) or [DC](#)) as well as [frequency](#) for AC. A person can sense electric current as low as 1 [mA \(rms\)](#) for 60 Hz AC and as low as 5 mA for DC. At around 10 mA, AC current passing through the arm of a 68-kilogram (150 lb) human can cause powerful muscle contractions; the victim is unable to voluntarily control muscles and cannot release an electrified object.^[19] This is known as the "let go threshold" and is a criterion for shock hazard in electrical regulations.

The current may, if it is high enough, cause tissue damage or [fibrillation](#) which can cause cardiac arrest; more than 30 mA^[12] of AC (rms, 60 Hz) or 300–500 mA of DC at high voltage can cause fibrillation.^{[14][20]} A sustained electric shock from AC at 120 [V](#), 60 Hz is an especially dangerous source of [ventricular fibrillation](#) because it usually exceeds the let-go threshold, while not delivering enough initial energy to propel the person away from the source. However, the potential seriousness of the shock depends on paths through the body that the currents take.^[14]

If the [voltage](#) is less than 200 V, then the human skin, more precisely the [stratum corneum](#), is the main contributor to the impedance of the body in the case of a [macroshock](#)—the passing of current between two contact points on the skin. The characteristics of the skin are non-linear however. If the voltage is above 450–600 V, then [dielectric breakdown](#) of the skin occurs.^[21] The protection offered by the skin is lowered by [perspiration](#), and this is accelerated if electricity causes muscles to contract above the let-go threshold for a sustained period of time.^[14]

If an electrical circuit is established by electrodes introduced in the body, bypassing the skin, then the potential for lethality is much higher if a circuit through the heart is established. This is known as a [microshock](#). Currents of only 10 μ A can be sufficient to cause fibrillation in this case with a probability of 0.2%.^[22]

Body resistance

The voltage necessary for electrocution depends on the current through the body and the duration of the current. [Ohm's law](#) states that the current drawn depends on the resistance of the body. The resistance of [human skin](#) varies from person to person and fluctuates between different times of day. The [NIOSH](#) states "Under dry conditions, the resistance offered by the human body may be as high as 100,000 ohms. Wet or broken skin may drop the body's resistance to 1,000 ohms," adding that "high-voltage electrical energy quickly breaks down human skin, reducing the human body's resistance to 500 ohms".^[23]

| Voltage | 5% | 50% | 95% |
|---------|----------------|----------------|----------------|
| 25 V | 1,750 Ω | 3,250 Ω | 6,100 Ω |
| 100 V | 1,200 Ω | 1,875 Ω | 3,200 Ω |
| 220 V | 1,000 Ω | 1,350 Ω | 2,125 Ω |
| 1000 V | 700 Ω | 1,050 Ω | 1,500 Ω |

The [International Electrotechnical Commission](#) gives the following values for the total body impedance of a hand to hand circuit for dry skin, large contact areas, 50 Hz AC currents (the columns contain the distribution of the impedance in the population [percentile](#); for example at 100 V 50% of the population had an impedance of 1875 Ω or less).^[24]

Skin

The voltage-current characteristic of human skin is non-linear and depends on many factors such as intensity, duration, history, and frequency of the electrical stimulus. Sweat gland activity, temperature, and individual variation also influence the voltage-current characteristic of skin. In addition to non-linearity, skin impedance exhibits asymmetric and time varying properties. These properties can be modeled with reasonable accuracy.^[25] Resistance measurements made at low voltage using a standard [ohmmeter](#) do not accurately represent the impedance of human skin over a significant range of conditions.

For sinusoidal electrical stimulation less than 10 volts, the skin voltage-current characteristic is quasilinear. Over time, electrical characteristics can become non-linear. The time required varies from seconds to minutes, depending on stimulus, electrode placement, and individual characteristics.

Between 10 volts and about 30 volts, skin exhibits non-linear but symmetric electrical characteristics. Above 20 volts, electrical characteristics are both non-linear and symmetric. Skin conductance can increase by several orders of magnitude in milliseconds. This should not be confused with [dielectric breakdown](#), which occurs at hundreds of volts. For these reasons, current flow cannot be accurately calculated by simply applying [Ohm's law](#) using a fixed resistance model.

Point of entry

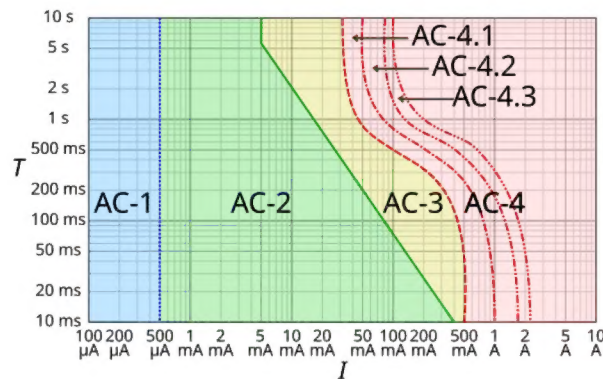
- [Macroshock](#): Current across intact skin and through the body. Current from arm to arm, or between an arm and a foot, is likely to traverse the heart, therefore it is much more dangerous than current between a leg and the ground. This type of shock by definition must pass into the body through the skin.
- [Microshock](#): Very small current source with a pathway directly connected to the heart tissue. The shock is required to be administered from inside the skin, directly to the heart i.e. a pacemaker lead, or a guide wire, conductive catheter etc. connected to a source of current. This is a largely theoretical hazard as modern devices used in these situations include protections against such currents.

Lethality

Electrocution

The earliest usage of the term "electrocution" cited by the Oxford English Dictionary was an 1889 newspaper reference to the method of execution then being considered.^[26] Shortly thereafter, in 1892, the term was used in *Science* to refer generically to death or injury caused by electricity.^[26]

Factors in lethality of electric shock



Log-log graph of the effect of alternating current I of duration T passing from left hand to feet as defined in IEC 60479-1.^[27]

AC-1: imperceptible

AC-2: perceptible but no muscle reaction

AC-3: muscle contraction with reversible effects

AC-4: possible irreversible effects

AC-4.1: up to 5% probability of ventricular fibrillation

AC-4.2: 5–50% probability of fibrillation

AC-4.3: over 50% probability of fibrillation

The lethality of an electric shock is dependent on several variables:

- **Current:** The higher the current, the more likely it is lethal. Since current is proportional to voltage when resistance is fixed ([ohm's law](#)), high voltage is an indirect risk for producing higher currents.
- **Duration:** The longer the shock duration, the more likely it is lethal—safety switches may limit time of current flow. Short high-current pulses, as from capacitors, are usually less dangerous than longer-lasting low-current shocks.
- **Pathway:** If current flows through vital organs, like the heart muscle, it is more likely to be lethal.
- **High voltage** (over about 600 volts). In addition to greater current flow, high voltage may cause dielectric breakdown at the skin, thus lowering skin resistance and allowing further increased current flow.
- **Medical implants:** [Artificial cardiac pacemakers](#) or [implantable cardioverter-defibrillators](#) (ICD) are sensitive to very small currents.^[28]
- **Pre-existing medical condition**^[29]
- **Age, body mass, and health status**^[30]
- **Sex:** Women are more vulnerable to electric shock than men.^[31]

Other issues affecting lethality are [frequency](#), which is an issue in causing cardiac arrest or muscular spasms. Very high frequency electric current causes tissue burning, but do not

stimulate the nerves strongly enough to cause cardiac arrest (see [electrosurgery](#)). Also important is the pathway: if the current passes through the chest or head, there is an increased chance of death. From a main circuit or power distribution panel the damage is more likely to be internal, leading to [cardiac arrest](#). Another factor is that cardiac tissue has a [chronaxie](#) (response time) of about 3 milliseconds, so electricity at frequencies of higher than about 333 Hz requires more current to cause fibrillation than is required at lower frequencies.

The comparison between the dangers of [alternating current](#) at typical power transmission frequencies (i.e., 50 or 60 Hz), and [direct current](#) has been a subject of debate ever since the [war of the currents](#) in the 1880s. Animal experiments conducted during this time suggested that alternating current was about twice as dangerous as direct current per unit of current flow (or per unit of applied voltage).

It is sometimes suggested that human lethality is most common with [alternating current](#) at 100–250 volts; however, death has occurred below this range, with supplies as low as 42 volts.^[32] Assuming a steady current flow (as opposed to a shock from a capacitor or from [static electricity](#)), shocks above 2,700 volts are often fatal, with those above 11,000 volts being usually fatal, though exceptional cases have been noted. According to the [Guinness Book of World Records](#), seventeen-year-old Brian Latasa survived a 230,000 volt shock on the tower of an ultra-high voltage line in [Griffith Park](#), Los Angeles on November 9, 1967.^[33] A news report of the event stated that he was "jolted through the air, and landed across the line", and though rescued by firemen, he sustained burns over 40% of his body and was completely paralyzed except for his eyelids.^[34] The shock with the highest voltage reported survived was that of Harry F. McGrew, who came in contact with a 340,000 volt transmission line in Huntington Canyon, Utah.^[35]

The severity and lethality of electric shocks generally depend on the duration and the amount of current passing through the human body. Frequency plays a role with AC and pulse DC. For example, a high frequency current has a higher ventricular fibrillation threshold than lower frequency. Also, shorter single pulses have higher thresholds than short pulses. Below 10 ms are usually believed to have a primarily charge dependent threshold and shock amplitude. Research shows that for very short electric pulse durations below 100 μ s the threshold curve converges into a constant charge criterion independent of peak current or RMS values. Even though the for both muscle and nerve stimulation including the heart and the brain. Heating is primarily determined by the amount of energy and is not related to stimulation. These definitions have been included into the IEC standard 60479-2 in opposite to IEC 60479-1 which addresses longer pulse durations above 10 ms for both DC and AC, which use a current over time duration curve based classification. These principles are used to determine the risks from capacitors, electric weapons, electric fences and other short pulsed low- and high-voltage electrical applications outside the medical field.

Prevention in points

Prevention of electrical injuries is one of the fundamental objectives of national [electrical codes](#) for permanently-installed electrical systems in buildings. Shock danger may be reduced by use of an [extra-low voltage](#) electrical system that is unlikely to expose a human to dangerous levels of current. Special isolated power systems may be used in applications such as [operating theatres](#), where electrical equipment must be used in proximity to a person unusually vulnerable to electrical shock. For electrical equipment used outdoors or in wet areas, an [Earth-leakage circuit breaker](#) known as a [residual-current device](#) or *ground fault circuit interrupter*, may provide protection from electrical current leakage.

Electrical devices have non-conductive [insulation](#) preventing contact with energized wires or parts, or may have conductive metal enclosures connected to earth [ground](#) so that users will not be exposed to dangerous voltage. [Double insulated](#) devices have a separate insulation system, distinct from the insulation required for the function of the device, and intended for protection of the user from electrical shock.

People and animals can be protected by installing electrical equipment out of reach of passers-by, such as on electrical [transmission towers](#), or by installation in an [electrical room](#) only accessible to authorized persons. [Stray current leakage](#) or electrical fault current may be diverted by [bonding](#) all conductive equipment enclosures together and to the earth. [Current passing through the earth](#) may also provide a hazard of electrical shock, so a ground grid may be installed around installations such as [electrical substations](#). [Lightning protection systems](#) are primarily installed to reduce property damage by lightning strikes, but may not entirely prevent electrical shock hazards. Persons outdoors during a lightning storm may be advised to take [precautions](#) to avoid electrical shock.

Where installation, or maintenance of electrical equipment is required, [interlock](#) devices may be used to ensure that all electrical sources are removed from the equipment before accessing normally energized parts. Administrative procedures such as [lockout-tagout](#) are used to protect workers from accidentally re-energizing equipment under repair. Where accidental contact with energized components is still possible, or where adjustment of an energized system is absolutely necessary, workers may be trained to use insulated or non-conductive tools, and [personal protective equipment](#) such as gloves, face shields, non-conductive boots, or cover-up mats. With proper training and equipment, [live-line maintenance](#) is routinely safely carried out on electrical [transmission lines](#) energized at hundreds of thousands of [volts](#).

Epidemiology

There were 550 reported electrocution deaths in the US in 1993, 2.1 deaths per million inhabitants. At that time, the incidence of electrocutions was decreasing.^[36] Electrocutions in the workplace make up the majority of these fatalities. From 1980–1992, an average of 411 workers were killed each year by electrocution.^[23] Workplace deaths caused by exposure to electricity in the U.S. increased by nearly 24% between 2015 and 2019, from 134 to 166. However, workplace electrical injuries dropped 23% between 2015 and 2019 from 2,480 to 1,900.^[37] In 2019, the top 5 states with the most workplace electrical fatalities were: (1) [Texas](#) (608); (2) [California](#) (451); (3) [Florida](#) (306); (4) [New York](#) (273); and (5) [Georgia](#) (207).^[38]

A recent study conducted by the National Coroners Information System (NCIS) in Australia^[39] has revealed 321 closed case fatalities (and at least 39 case fatalities still under coronial investigation) that had been reported to Australian coroners where a person died from electrocution between July 2000 and October 2011.^[40]

In Sweden, Denmark, Finland and Norway the number of electric deaths per million inhabitants was 0.6, 0.3, 0.3 and 0.2, respectively, in the years 2007–2011.^[41]

In Nigeria, analysis of [Nigerian Electricity Regulatory Commission](#) data found 126 recorded electrocution deaths and 68 serious injuries in 2020 and the first half of 2021.^[42] Most electrocutions are accidental and caused by faulty equipment or poor adherence to regulations. Some distribution companies in Nigeria have higher death rates than others; in 2017, there were 26 deaths on the Abuja grid, while the Ikeja grid caused only 2 deaths.

People who survive electrical trauma may develop a host of injuries including loss of consciousness, seizures, aphasia, visual disturbances, headaches, tinnitus, paresis, and memory disturbances.^[43] Even without visible burns, electric shock survivors may be faced with long-term muscular pain and discomfort, exhaustion, headache, problems with peripheral nerve conduction and sensation, inadequate balance and coordination, among other symptoms. Electrical injury can lead to problems with neurocognitive function, affecting speed of mental processing, attention, concentration, and memory. The high frequency of psychological problems is well established and may be multifactorial.^[43] As with any traumatic and life-threatening experience, electrical injury may result in post traumatic psychiatric disorders.^[44] There exist several non-profit research institutes that coordinate rehabilitation strategies for electrical injury survivors by connecting them with clinicians that specialize in diagnosis and treatment of various traumas that arise as a result of electrical injury.^{[45][46]}

Deliberate uses

Medical uses

Electric shock is also used as a medical therapy, under carefully controlled conditions:

- [Electroconvulsive therapy](#) or ECT, a psychiatric therapy for [mental disorders](#)
- As a surgical tool for cutting or coagulation in [electrosurgery](#). An electrosurgical unit (ESU) uses high currents (e.g. 10 amperes) at high frequency (e.g. 500 kHz) with various schemes of amplitude modulation to cut or coagulate
- As a treatment for fibrillation or irregular heart rhythms: see [Defibrillation](#) and [Cardioversion](#)
- As a method of [pain relief](#): see [Transcutaneous electrical nerve stimulation](#) (TENS)
- As a treatment for [excessive sweating](#) with a process called [iontophoresis](#)
- [Electrodiagnosis](#), for example [nerve conduction studies](#) and [electromyography](#)
- [Electroporation](#) for gene delivery

Entertainment



Electrifying machine at [Musée Mécanique](#) that actually works with vibration^[47]

Mild electric shocks are also used for entertainment, especially as a [practical joke](#) for example in such devices as a shocking pen or a [shocking gum](#). However devices such as a [joy buzzer](#) and most other machines in [amusement parks](#) today only use vibration that feels somewhat like an electric shock to someone not expecting it.

Policing and personal defense

[Electroshock weapons](#) are [incapacitant weapons](#) used for subduing a person by administering electric shock to disrupt superficial [muscle](#) functions. One type is a conductive energy device (CED), an electroshock gun popularly known by the brand name "[Taser](#)", which fires projectiles that administer the shock through a thin, flexible wire. Although they are illegal for personal use in many jurisdictions, Tasers have been marketed to the general public.^[48] Other electroshock weapons such as stun guns, stun batons ("cattle prods"), and [electroshock belts](#) administer an electric shock by direct contact.

[Electric fences](#) are barriers that use electric shocks to deter animals or people from crossing a boundary. The voltage of the shock may have effects ranging from uncomfortable, to painful or even lethal. Most electric fencing is used today for [agricultural fencing](#) and other forms of animal control purposes, though it is frequently used to enhance security of restricted areas, and there exist places where lethal voltages are used.

Torture

Electric shocks are used as a method of [torture](#), since the received voltage and current can be controlled with precision and used to cause [pain](#) and fear without always visibly harming the victim's body.

Electrical torture has been used in war and by repressive regimes since the 1930s.^[49] During the [Algerian War](#) electrical torture was used by French military forces.^[50] [Amnesty International](#) published a statement that Russian military forces in [Chechnya](#) tortured local women with electric shocks by attaching wires onto their breasts.^[51]

The use of electric shocks to torture political prisoners of the [Brazilian military dictatorship](#) (1964 - 1985) is detailed in the final report of the [National Truth Commission](#), published December 10, 2014.^[52]

The *parrilla* ([Spanish](#) for 'grill') is a method of [torture](#) whereby the victim is strapped to a metal frame and subjected to electric shock.^[53] It has been used in a number of contexts in South America. The *parrilla* was commonly used at [Villa Grimaldi](#), a prison complex maintained by [Dirección de Inteligencia Nacional](#), a part of the [Pinochet](#) regime.^[54] In the 1970s, during the [Dirty War](#), the *parrilla* was used in Argentina.^[55] [Francisco Tenório Júnior](#) (known as Tenorinho), a Brazilian piano player, was subjected to the *parrilla* during the [military dictatorship in Brazil](#).^[56]

The [Islamic State](#) has used electric shocks to torture and kill captives.^{[57][58][59]}

Advocates for the [mentally ill](#) and some [psychiatrists](#) such as [Thomas Szasz](#) have asserted that electroconvulsive therapy (ECT) is torture when used without a *bona fide* medical benefit against recalcitrant or non-responsive patients.^{[60][61][62]}

The [Judge Rotenberg Center](#) in [Canton, Massachusetts](#) has been condemned for torture by the [United Nations special rapporteur on torture](#) for its use of electric shocks as punishment as part of its [behavior modification](#) program.^{[63][64]}

Japanese [serial killer Futoshi Matsunaga](#) used electric shocks to control his victims.^[65]

Capital punishment



[Electric chair in Sing Sing](#)

Electric shock delivered by an [electric chair](#) is sometimes used as an official means of [capital punishment](#) in the United States, although its use has become rare from the 1990s onward due to the adoption of [lethal injection](#). Although some original proponents of the electric chair considered it to be a more humane execution method than [hanging](#), [shooting](#), [poison gassing](#), etc., it has now generally been replaced by lethal injections in states that practice capital punishment. Modern reporting has claimed that it sometimes takes several shocks to be lethal, and that the condemned person may actually catch fire before death.

Other than in parts of the United States, only the [Philippines](#) reportedly has used this method, from 1926 to 1976. It was intermittently replaced by the [firing squad](#), until the death penalty was abolished in that country. Electrocution remains legal in 9 states (primary method in [South Carolina](#), optional in [Alabama](#) and Florida, optional if sentenced before a certain date in [Arkansas](#), [Kentucky](#) and [Tennessee](#), can only be used if other methods are found to be unconstitutional in [Louisiana](#), [Mississippi](#) and [Oklahoma](#)) of the United States.^[66]

See also

- [Electrical burn](#)
- [Electromagnetism](#)
- [Graduated electronic decelerator](#)
- [Lichtenberg figure](#)
- [Lightning injury](#)
- [Milgram experiment](#)

References

1. Zemaitis MR, Foris LA, Lopez RA, Huecker MR (January 2020). "Electrical Injuries". *StatPearls [Internet]*. PMID 28846317 (<https://pubmed.ncbi.nlm.nih.gov/28846317>) .
2. "Electrical injury: MedlinePlus Medical Encyclopedia" (<https://medlineplus.gov/ency/article/000053.htm>) . *medlineplus.gov*. Retrieved 2 October 2023.
3. Boon, Elizabeth; Parr, Rebecca; 20,000Dayananda, Samarawickrama (2012). *Oxford Handbook of Dental Nursing* (<https://books.google.com/books?id=dx9FAgAAQBAJ&q=%22electric+shock&pg=PA132>) . Oxford University Press. p. 132. ISBN 978-0191629860. Archived (<https://web.archive.org/web/20170306102959/https://books.google.com/books?id=dx9FAgAAQBAJ&pg=PA132&dq=%22electric+shock>) from the original on 2017-03-06.
4. Reilly 1998, p. 1
5. "Electrical injuries – Electrical safety" (<https://www.hse.gov.uk/electricity/injuries.htm>) . *www.hse.gov.uk*. Retrieved 2 October 2023.
6. Leslie Alexander Geddes, Rebecca A. Roeder ,*Handbook of Electrical Hazards and Accidents* Lawyers & Judges Publishing Company, 2006 ISBN 0913875449, page 29
7. Gentges, Joshua; Schieche, Christoph (November 2018). "Electrical injuries in the emergency department: an evidence-based review". *Emergency Medicine Practice*. **20** (11): 1–20. ISSN 1559-3908 (<https://search.worldcat.org/issn/1559-3908>) . PMID 30358379 (<https://pubmed.ncbi.nlm.nih.gov/30358379>) .
8. "Introduction to electrical safety – HSE" (<https://www.hse.gov.uk/electricity/precautions.htm>) . *www.hse.gov.uk*. Retrieved 2 October 2023.
9. "Electrical Injuries – Injuries; Poisoning" (<https://www.merckmanuals.com/professional/injuries-poisoning/electrical-and-lightning-injuries/electrical-injuries>) . *Merck Manuals Professional Edition*. Retrieved 9 May 2020.

10. Wesner, Marni; Hickie, John (2013). "Long-term sequelae of electrical injury" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3771718>) . *Can Fam Physician*. **59** (9): 935–939. PMC 3771718 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3771718>) . PMID 24029506 (<https://pubmed.ncbi.nlm.nih.gov/24029506>) .
11. Lee, R. C.; Canaday, D. J.; Hammer, S. M. (1993). "Transient and stable ionic permeabilization of isolated skeletal muscle cells after electrical shock". *The Journal of Burn Care & Rehabilitation*. **14** (5): 528–40. doi:10.1097/00004630-199309000-00007 (<http://doi.org/10.1097/00004630-199309000-00007>) . PMID 8245107 (<https://pubmed.ncbi.nlm.nih.gov/8245107>) .
12. ucsb.edu – Electrical Safety Information – Physics Department, UCSB (http://web.physics.ucsb.edu/~phys13CH/electrical_safety.pdf) Archived (https://web.archive.org/web/20131023060415/http://web.physics.ucsb.edu/~phys13CH/electrical_safety.pdf) 2013-10-23 at the Wayback Machine, 2012-01-09
13. Waldmann V, Narayanan K, Combes N, Jost D, Jouven X, Marijon E (April 2018). "Electrical cardiac injuries: current concepts and management" (<https://doi.org/10.1093/eurheartj/ehx142>) . *European Heart Journal*. **39** (16): 1459–1465. doi:10.1093/eurheartj/ehx142 (<https://doi.org/10.1093/eurheartj/ehx142>) . PMID 28444167 (<https://pubmed.ncbi.nlm.nih.gov/28444167>) .
14. Clifford D. Ferris, *Electric Shock*, chapter 22.1 in Jerry C. Whitaker (ed.) *The Electronics Handbook*, CRC Press, 2005, ISBN 0-8493-1889-0, pp. 2317–2324
15. Wiggers, Carl J.; Bell, James R.; Paine, Margaret (2003-07-08). "Studies of Ventricular Fibrillation Caused by Electric Shock" (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6932455>) . *Annals of Noninvasive Electrocardiology*. **8** (3): 252–261. doi:10.1046/j.1542-474X.2003.08316.x (<https://doi.org/10.1046/j.1542-474X.2003.08316.x>) . ISSN 1082-720X (<https://search.worldcat.org/issn/1082-720X>) . PMC 6932455 (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6932455>) . PMID 14510663 (<https://pubmed.ncbi.nlm.nih.gov/14510663>) .
16. Electric Stunning of Pigs and Sheep (<http://www.grandin.com/humane/elec.stun.html>) Archived (<https://web.archive.org/web/20160306103752/http://www.grandin.com/humane/elec.stun.html>) 2016-03-06 at the Wayback Machine
17. "Industry Backs IEEE-NFPA Arc Flash Testing Program with Initial Donations of \$1.25 Million" (https://web.archive.org/web/20080302213538/http://standards.ieee.org/announcements/pr_FINArc.html) . IEEE. 14 July 2006. Archived from the original (http://standards.ieee.org/announcements/pr_FINArc.html) on 2 March 2008. Retrieved 2008-01-01.
18. "Arc_flash_protection.php – Arc Flash" (http://www.arcflash.com.au/arc_flash_protection.php) . *www.arcflash.com.au*.

19. John Cadick et al. (ed.) *Electrical Safety Handbook Third Edition*, McGraw Hill, 2005 ISBN 0-07-145772-0 page 1-4
20. Jack Hsu (2000). "Electric Current Needed to Kill a Human" (<http://hypertextbook.com/facts/2000/JackHsu.shtml>) . *The Physics Factbook*. Archived (<https://web.archive.org/web/20131023060224/http://hypertextbook.com/facts/2000/JackHsu.shtml>) from the original on 2013-10-23. Retrieved January 14, 2018.
21. Reilly 1998, p. 30
22. Norbert Leitgeb (6 May 2010). *Safety of Electromedical Devices: Law – Risks – Opportunities* (<https://books.google.com/books?id=FpSH-VM5TYkC&pg=PA122>) . Springer Science & Business Media. p. 122. ISBN 978-3-211-99683-6. Archived (<https://web.archive.org/web/20170401235716/https://books.google.com/books?id=FpSH-VM5TYkC&pg=PA122>) from the original on 1 April 2017.
23. "Publication No. 98-131: Worker Deaths by Electrocution" (<https://www.cdc.gov/niosh/docs/98-131/pdfs/98-131.pdf>) (PDF). National Institute for Occupational Safety and Health. Archived (<https://web.archive.org/web/20081011191854/http://www.cdc.gov/niosh/docs/98-131/pdfs/98-131.pdf>) (PDF) from the original on 2008-10-11. Retrieved 2008-08-16.
24. Reilly 1998, p. 43
25. "The Voltage Current Characteristic of the Human Skin" (<http://repository.up.ac.za/bitstream/handle/2263/28072/dissertation.pdf?sequence=1>) (PDF). University of Pretoria. Archived (<https://web.archive.org/web/20151017084822/http://repository.up.ac.za/bitstream/handle/2263/28072/dissertation.pdf?sequence=1>) (PDF) from the original on 2015-10-17.
26. "electrocution" (<https://www.oed.com/view/Entry/60282>) . *Oxford English Dictionary* (Online ed.). Oxford University Press. (Subscription or participating institution membership (<https://www.oed.com/public/login/loggingin#withyourlibrary>) required.)
27. Weineng Wang, Zhiqiang Wang, Xiao Peng, *Effects of the Earth Current Frequency and Distortion on Residual Current Devices* (http://papersub.ivypub.org/Global/DownloadService.aspx?PARAMS=Sm91cm5hbElEXjM3OF5JRF4xNDAzOQ_0_0) Archived (https://web.archive.org/web/20141108110449/http://papersub.ivypub.org/Global/DownloadService.aspx?PARAMS=Sm91cm5hbElEXjM3OF5JRF4xNDAzOQ_0_0) 2014-11-08 at the Wayback Machine, Scientific Journal of Control Engineering, Dec 2013, Vol 3 Issue 6 pp 417–422
28. Claire M. Blandford (21 April 2016). *Passing the Primary FRCA SOE: A Practical Guide* (<https://books.google.com/books?id=rfnUCwAAQBAJ&pg=PA117>) . Cambridge University Press. pp. 117–. ISBN 978-1-107-54580-9. Archived (<https://web.archive.org/web/20180102234454/https://books.google.com/books?id=rfnUCwAAQBAJ&pg=PA117>) from the original on 2 January 2018.

29. Andrei G. Pakhomov; Damijan Miklavcic; Marko S. Markov (2 June 2010). *Advanced Electroporation Techniques in Biology and Medicine* (<https://books.google.com/books?id=sTHNBQAAQBAJ&pg=PA498>) . CRC Press. pp. 498–. ISBN 978-1-4398-1907-4. Archived (<https://web.archive.org/web/20180102234454/https://books.google.com/books?id=sTHNBQAAQBAJ&pg=PA498>) from the original on 2 January 2018.
30. John M Madden (20 January 2017). *Electrical Safety and the Law* (<https://books.google.com/books?id=jCsIDwAAQBAJ&pg=PA3>) . Taylor & Francis. p. 3. ISBN 978-1-317-20851-8. Archived (<https://web.archive.org/web/20180102234454/https://books.google.com/books?id=jCsIDwAAQBAJ&pg=PA3>) from the original on 2 January 2018.
31. "IEC 60479-1:2018 | IEC Webstore" (<https://webstore.iec.ch/publication/62980#:~:text=IEC%2060479-1:2018>) . *webstore.iec.ch*. Retrieved 2024-06-20.
32. "The Fatal Current" (https://www.physics.ohio-state.edu/~p616/safety/fatal_current.html) . *OSU Physics*. Ohio State University. Archived (https://web.archive.org/web/20180103133438/https://www.physics.ohio-state.edu/~p616/safety/fatal_current.html) from the original on 3 January 2018. Retrieved 4 March 2015.
33. "According to Guinness (comic)" (<https://news.google.com/newspapers?nid=1350&dat=19780428&id=qAtPAAAAIBAJ&pg=3583,2551486>) . Toledo Blade. 1978-04-28.
34. "Firemen risk death to save teenager" (<https://news.google.com/newspapers?nid=1356&dat=19671124&id=JIdPAAAAIBAJ&pg=3519,5256084>) . Ocala Star-Banner. 1967-11-24.
35. "Guinness World Records" (https://archive.org/stream/in.ernet.dli.2015.115614/2015.115614.Guinness-World-Records_djvu.txt) .
36. Folliot, Dominique (1998). "Electricity: Physiological Effects" (<https://web.archive.org/web/20070228084602/http://www.ilo.org/encyclopedia/?doc&nd=857100207&nh=0>) . *Encyclopaedia of Occupational Health and Safety, Fourth Edition*. Archived from the original (<http://www.ilo.org/encyclopedia/?doc&nd=857100207&nh=0>) on 2007-02-28. Retrieved 2006-09-04.
37. "ESFI Occupational Injury and Fatality Statistics" (<https://www.esfi.org/workplace-injury-and-fatality-statistics>) . *www.esfi.org*. Retrieved 2021-03-23.
38. "Census of Fatal Occupational Injuries Summary, 2019" (<https://www.bls.gov/news.release/cfoi.nr0.htm>) . *www.bls.gov*. Retrieved 2021-03-23.
39. National Coroners Information System, NCIS (<http://www.ncis.org.au>) Archived (<https://web.archive.org/web/20120221192843/http://ncis.org.au/>) 2012-02-21 at the Wayback Machine

40. [Electrocution Related Deaths – National Coroners Information System \(NCIS\) Fact-Sheet, January 2012](http://www.ncis.org.au/web_pages/Feb%202012%20FACT-SHEET%20-%20Electrocution%20related%20deaths.pdf) (http://www.ncis.org.au/web_pages/Feb%202012%20FACT-SHEET%20-%20Electrocution%20related%20deaths.pdf) Archived (https://web.archive.org/web/20120317093225/http://www.ncis.org.au/web_pages/Feb%202012%20FACT-SHEET%20-%20Electrocution%20related%20deaths.pdf) March 17, 2012, at the [Wayback Machine](#)
41. Kinnunen, Minna (2013). "Electrical accident hazards in the Nordic countries" (http://www.tukes.fi/Tiedostot/sahko_ja_hissit/Diplomityo_Kinnunen_2013.pdf) (PDF). *Master's thesis, Tampere University of Technology*. p. 19. Archived (https://web.archive.org/web/20140327012550/http://tukes.fi/Tiedostot/sahko_ja_hissit/Diplomityo_Kinnunen_2013.pdf) (PDF) from the original on 2014-03-27. Retrieved 2013-06-10.
42. "NERC: 126 Nigerians Killed, 68 Injured in Electricity-related Accidents in 18 Months – THISDAYLIVE" (<https://www.thisdaylive.com/index.php/2021/12/20/nerc-126-nigerians-killed-68-injured-in-electricity-related-accidents-in-18-months>) . www.thisdaylive.com.
43. Pliskin, N. H.; Meyer, G. J.; Dolske, M. C.; Heilbronner, R. L.; Kelley, K. M.; Lee, R. C. (1994). "Neuropsychiatric Aspects of Electrical Injury". *Annals of the New York Academy of Sciences*. **720** (1): 219–23. Bibcode:1994NYASA.720..219P (<https://ui.adsabs.harvard.edu/abs/1994NYASA.720..219P>) . doi:10.1111/j.1749-6632.1994.tb30450.x (<https://doi.org/10.1111%2Fj.1749-6632.1994.tb30450.x>) . PMID 8010642 (<https://pubmed.ncbi.nlm.nih.gov/8010642>) . S2CID 14913272 (<https://api.semanticscholar.org/CorpusID:14913272>) .
44. Grigorovich, Alisa; Gomez, Manuel; Leach, Larry; Fish, Joel (2013). "Impact of Posttraumatic Stress Disorder and Depression on Neuropsychological Functioning in Electrical Injury Survivors". *Journal of Burn Care & Research*. **34** (6): 659–65. doi:10.1097/BCR.0b013e31827e5062 (<https://doi.org/10.1097%2FBCR.0b013e31827e5062>) . PMID 23412330 (<https://pubmed.ncbi.nlm.nih.gov/23412330>) . S2CID 3698828 (<https://api.semanticscholar.org/CorpusID:3698828>) .
45. <http://www.cetri.org> Archived (<https://web.archive.org/web/20101223121712/http://www.cetri.org/>) 2010-12-23 at the [Wayback Machine](#)
46. "St. Johns Rehab – Electrical Injury Program – Sunnybrook Hospital" (<http://sunnybrook.ca/content/?page=sjr-patvis-prog-electrical>) . Archived (<https://web.archive.org/web/20131004215625/http://sunnybrook.ca/content/?page=sjr-patvis-prog-electrical>) from the original on 2013-10-04. Retrieved 2013-10-03.
47. "Addams Family Generator – Arcade by H. Betti Industries, Inc" (http://www.arcade-museum.com/game_detail.php?game_id=10550) . www.arcade-museum.com.

48. International Association of Chiefs of Police, *Electro Muscular Disruption Technology: A Nine-Step Strategy for Effective Deployment* (<http://www.theiacp.org/research/CuttingEdge/EMDT9Steps.pdf>) Archived (<https://web.archive.org/web/20131210211811/http://www.theiacp.org/research/CuttingEdge/EMDT9Steps.pdf>) December 10, 2013, at the Wayback Machine, 2005
49. Technological Invention and Diffusion of Torture Equipment The Strange Case of Electric Torture Instruments in the Early 20th Century (http://academic.reed.edu/poli_sci/faculty/rejali/rejali/articles/electric.html) Archived (https://web.archive.org/web/20100305072316/http://academic.reed.edu/poli_sci/faculty/rejali/rejali/articles/electric.html) March 5, 2010, at the Wayback Machine
50. Arens, Marianne; Thull, Françoise (April 9, 2001). "Torture in the Algerian war (1954–62) The Algerian war 1954–62" (<https://web.archive.org/web/20171025060200/http://www.wsws.org/en/articles/2001/04/alg-a09.html>) . *World Socialist Web Site*. International Committee of the Fourth International (ICFI). Archived from the original (<http://www.wsws.org/en/articles/2001/04/alg-a09.html>) on 2017-10-25. Retrieved 2 December 2017.
51. "Russian Federation Preliminary briefing to the UN Committee against Torture" (<https://web.archive.org/web/20090516061641/http://www.amnesty.org/en/library/info/EUR46/014/2006>) . Archived from the original on May 16, 2009. Retrieved February 24, 2012.
52. Salomão, Lucas (10 December 2014). "Comissão relata modalidades de tortura usadas contra presos políticos" (<https://g1.globo.com/politica/noticia/2014/12/comissao-relata-modalidades-de-tortura-usadas-contra-presos-politicos.html>) . G1 (in Portuguese). Retrieved 22 July 2024.
53. *Chile: Evidence of Torture* (<https://archive.org/details/chileevidenceoft0000amne>) . Amnesty International. 1983. pp. 3, 6. ISBN 9780862100537. OCLC 1148222200 (<https://search.worldcat.org/oclc/1148222200>) .
54. Gomez-Barris, Macarena (2009). *Where Memory Dwells: Culture and State Violence in Chile* (<https://books.google.com/books?id=LsJNDwAAQBAJ>) . University of California Press. pp. 46–47. ISBN 978-0-520-25583-8.
55. Feitlowitz, Marguerite (1999). *A Lexicon of Terror: Argentina and the Legacies of Torture* (<https://archive.org/details/lexiconofterrora00feit>) . New York: Oxford University Press. pp. 49, 57. ISBN 9780195134162. OCLC 1035915088 (<https://search.worldcat.org/oclc/1035915088>) .
56. McSherry, J. Patrice (2012-07-10). *Predatory States: Operation Condor and Covert War in Latin America* (<https://books.google.com/books?id=tSDg6xa4z2YC>) . Rowman & Littlefield. p. 188. ISBN 978-0-7425-6870-9.

57. "ISIS executes 22 persons by electrocution in central Mosul" (<http://www.iraqinews.com/iraq-war/isis-executes-22-persons-electrocution-central-mosul/>) . Iraqi News. 27 October 2016. Archived (<https://web.archive.org/web/20161030075305/http://www.iraqinews.com/iraq-war/isis-executes-22-persons-electrocution-central-mosul/>) from the original on 2016-10-30. Retrieved 2024-03-04.
58. "ISIS electrocutes 30 civilians to death in central Mosul - Iraqi News" (<https://web.archive.org/web/20161110044037/http://www.iraqinews.com/iraq-war/isis-electrocutes-30-civilians-death-central-mosul/>) . Archived from the original (<http://www.iraqinews.com/iraq-war/isis-electrocutes-30-civilians-death-central-mosul/>) on 2016-11-10. Retrieved 2024-03-04.
59. "Inside ISIS death prison with metal electrocution beds, secret tunnels and agonising final messages scrawled on walls" (<https://www.mirror.co.uk/news/world-news/inside-isis-death-prison-metal-11387192>) . Daily Mirror. 22 October 2017. Retrieved 2024-03-04.
60. Israel, Matthew. "History and Basic Principles of JRC" (<https://web.archive.org/web/20080118082229/http://www.judgerc.org/history.html>) . Archived from the original (<http://www.judgerc.org/history.html>) on 2008-01-18. Retrieved 2007-12-22.
61. Gonnerman, Jennifer (20 August 2007). "School of Shock" (https://www.motherjones.com/news/feature/2007/09/school_of_shock.html) . Mother Jones Magazine. Archived (https://web.archive.org/web/20071222132030/https://www.motherjones.com/news/feature/2007/09/school_of_shock.html) from the original on 22 December 2007. Retrieved 2007-12-22.
62. Wen, P (2008-01-17). "Showdown over shock therapy" (http://www.boston.com/news/local/articles/2008/01/17/showdown_over_shock_therapy/) . The Boston Globe. Archived (https://web.archive.org/web/20100313093523/http://www.boston.com/news/local/articles/2008/01/17/showdown_over_shock_therapy/) from the original on 2010-03-13. Retrieved 2008-01-26.
63. "UN Calls Shock Treatment at Mass. School 'Torture' " (<https://abcnews.go.com/Nightline/showdown-over-shock-therapy-massachusetts-school/story?id=11047334>) . ABC News. Retrieved 2020-08-04.
64. Fortin, Jacey (2020-03-06). "F.D.A. Bans School Electric Shock Devices" (<https://www.nytimes.com/2020/03/06/us/electric-shock-fda-ban.html>) . *The New York Times*. ISSN 0362-4331 (<https://search.worldcat.org/issn/0362-4331>) . Retrieved 2020-08-04.
65. "Serial killer's death sentence upheld" (<http://arquivo.pt/wayback/20160515124846/http://www.asahi.com/english/Herald-asahi/TKY200709270058.html>) . Asahi Shimbun. 2007-09-27. Archived from the original (<http://www.asahi.com/english/Herald-asahi/TKY200709270058.html>) on 2016-05-15. Retrieved 2008-03-21.

66. Death Penalty Information Center (<http://www.deathpenaltyinfo.org/state/>) Archived (<https://web.archive.org/web/20150523143211/http://www.deathpenaltyinfo.org/state/>) May 23, 2015, at the [Wayback Machine](#)

Cited sources

- Reilly, J. Patrick (1998). *Applied Bioelectricity: From Electrical Stimulation to Electropathology* (2nd ed.). Springer. ISBN 978-0-387-98407-0. LCCN 97048860 (<https://lcn.loc.gov/97048860>) . OCLC 38067651 (<https://search.worldcat.org/oclc/38067651>) .

External links

- National Institute for Occupation Safety & Health: Worker Deaths by Electrocution (<https://www.cdc.gov/niosh/docs/98-131/>) , a CDC study
- Effect of Electric Shock Currents on Humans (<http://www.apseee.com/effect-of-electric-shock-currents-on-humans/>)
- Electrical injury and its effects (<https://electricknowhow.com/electrical-injuries-effects-and-causes/>)